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SPECIAL TREATMENTS FOR HIGHWAY NOISE BARRIERS

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INTRODUCTION

This paper summarizes an investigation of the acoustic, aesthetic, and economic performance of five special barrier treatments (absorptive T-top, Y-top, slanted-top, single barrier absorptive, and parallel barrier absorptive) applied to noise barriers in four highway projects in Seattle, Washington, and another in Spokane, Washington. A standard barrier design, using thin, vertical, reflective barriers, was created for each of the four specific projects, and one or more of the special barrier treatments was then applied. The effectiveness of the five special treatments, which had been selected in an earlier phase of the research performed on behalf of the Washington State Department of Transportation, was compared to that of the conventional barriers.

The overall purpose of this phase of the research project was to test the five special barrier treatments analytically on several highway projects, thus gaining definitive information about their real potential and enabling the sponsor to implement pilot projects at a later date. The third phase of the project [Cohn 1996] was the construction of a scale modeling laboratory facility in which the five sites were modeled, and the effects of the special barrier treatments were tested. This resulted in a modified list of "rules of thumb" which could be applied as adjustments to the insertion loss values obtained for conventional barriers.

Background

During the last 20 years, state highway agencies have constructed more than 700 linear miles of noise barriers in the United States. Most of these barriers have been vertical, reflective walls made of concrete, wood, or steel. The standard barrier top for these walls is a "knife-edge," providing a single diffraction edge with a reflective diffraction zone [Barry 1978]. Clearly, many other types of barriers exist, including earth berms and barriers with absorptive or partially absorptive surfaces. Other barrier shapes can also be used, such as slanted tops that displace the diffraction zone horizontally, or T- or Y-tops that produce a double-diffraction zone.

For several years, the Washington State Department of Transportation (WSDOT) has sponsored research aimed at improving the performance of its noise barriers. This research has focused on shapes and materials that could decrease cost and improve performance and aesthetics. Phase I of the research was a comprehensive literature review [Cohn 1993] which gathered together all known information on the performance of barrier edges and surfaces. Phase I identified five special treatments as potentially useful to WSDOT:

1) absorptive T-top
2) Y-top
3) slanted-top
4) single wall absorptive
5) parallel absorptive

Phase II of the research [Cohn 1995] applied these special treatments to four actual noise barrier projects in Washington State (Fourth Avenue, Magnolia Road, Kent Commons Play Field, and Spokane Community College Area). Phase III, which was recently completed, was a scale-modeling study of the four projects to confirm the performance of the special treatments in the laboratory. With the conclusion of Phase III, WSDOT is now able to construct some of the special treatments and test them in a pilot study. If such tests are successful, WSDOT will then be able to implement the special treatments throughout its noise barrier program. At this writing, WSDOT is searching for candidate projects for the pilot study. The five projects which were the subject of Phases II and III are not available due to the scheduling of their construction. These projects are not likely to be constructed until sometime in the next century.

ACOUSTIC CONSIDERATIONS

Within certain limitations, special noise barriers perform better acoustically than conventional barriers. The principal limitation is maintaining an adequate line-of-sight break (the difference between the height of the barrier and the location at which the line-of-sight intersects the barrier). Since the dominant wavelength for broadband highway noise is approximately 2-3 feet, a special noise barrier must protrude at least that distance through the line of sight to perform as expected [Cohn 1993]. As long as a 2-3 foot line-of-sight break is maintained, a shorter conventional barrier should perform as well as a taller conventional barrier.

Shaped-barrier tops (absorptive T-top, Y-top, and slanted-top barriers) are not recommended when barrier heights exceed 13 feet because the benefit/cost ratio generally peaks at this point. However, if line of sight breaks are maintained, increased acoustic performance can be achieved regardless of barrier height. Regarding barrier surface treatments, absorptive materials could be applied with success to almost any project with single-wall barriers, as long as line of sight breaks are maintained, to gain additional insertion loss. Unlike single-wall absorptive barriers, absorptive parallel barriers are limited to heights greater than 10 feet, because only at this height will multiple reflections cause enough insertion loss degradation to warrant application of absorptive materials.

The enhanced acoustic performance of each special noise barrier varies as a result of the different mechanisms used by these barriers: double diffraction provided by a T-top or Y-top section, movement of the diffraction zone achieved by slanting the upper-third height of a conventional barrier, and sound wave energy absorption created by applying absorptive material to a T-top section or vertical wall [Cohn 1993].

Scale Modeling Study

A large room (a former retail establishment) was used in a deserted building on the University of Louisville campus. A 1000-2000 section of each site was modeled at a 50:1 scale, with one or two receiver locations tested at each site. An artificial noise source (spark) was used to model the traffic, and a desktop computer/data acquisition and analysis system was employed to gather and manipulate the data. Scale modeling protocols were taken from two studies funded by the US Federal Highway Administration [Anderson 1979, and Hayek 1990]. The Hayek study was used to assist in selecting the absorptive materials for the ground cover and barriers.

The accuracy of the scale modeling facility was confirmed by a series of calculations with the STAMINA 2.0/OPTIMA program, which were then reproduced by the scale modeling results. For 12 locations, the average difference in insertion loss between measured (scale model) and calculated (STAMINA 2.0/OPTIMA) was 1.6 dB, which was found to be statistically insignificant and within normal bounds of STAMINA 2.0/OPTIMA accuracy.

Rules of Thumb

The Phase II study produced a series of rules of thumb that were based on existing theory, laboratory, and field data. After applying these rules of thumb to the five actual projects through the use of the STAMINA 2.0/OPTIMA computer programs [Bowlby 1982], they were then adjusted in the scale modeling phase of the study. The resulting rules of thumb are:

Absorptive T-top barriers: 0.7-1 dB per foot additional attenuation (with minimum top width of 3 feet

Y-top barriers: 0.4 dB per foot additional attenuation (with minimum top width of 3 feet)

Absorptive single barriers: 1-2 dB additional attenuation (depending on depth into shadow zone) with minimum 3 foot absorptive strip at the top of the barrier

Absorptive parallel barriers: IL degradation eliminated with NRC at least 0.65

Slanted top barriers: No significant effect on attenuation, but positive aesthetic impacts likely

Analysis Process

The steps in the process for decisions to apply special treatments are:

1) Establish a conventional barrier design
2) Calculate line of sight breaks for the conventional design

3) Lower barrier heights to accommodate minimum line of sight break and calculate resulting insertion losses
4) Add enhanced insertion loss values based rules of thumb to determine effects of special treatments
5) Adjust barrier heights back up to reach original insertion losses, if needed
6) Calculate costs of conventional and special barrier designs
7) Identify additional maintenance costs and aesthetic impacts of particular special treatments
8) Select final barrier design: conventional, special, or combination

CONCLUSION

The level of funding for the three phases of this project was limited. Therefore, the rules of thumb developed through the literature review and modified by the scale modeling effort are not fully defined mathematically nor are they definitive. However, they do provide the sponsor with adequate justification to proceed with pilot projects. WSDOT is currently looking for several imminent barrier projects on which to build full scale absorptive T-top and single wall barrier systems. Once constructed, detailed noise measurements will be performed to ascertain performance enhancements resulting from the special barrier treatments. The authors are currently designing the details of the T-top and single wall systems, as well as the measurement methodology. Hopefully, the result of all this effort will be some field tested, reliable methods to improve barrier performance.

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